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Unusual Behavior of Cesium in the Florida Biosphere

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Radionuclides in fallout from nuclear weapons testing have provided tracers for studying various facets of the environment on a large scale. Measurements of one of these, cesium-137 (^{137}Cs), strongly indicate the possibility of a mechanism in the Florida environment which results in an unusual biospheric concentration of this nuclide.

Cesium ecology in Florida has not been completely described. From a human exposure point of view, however, the following seven-point description has been developed from results of investigations by this laboratory and other available data.

1. Cesium-137 levels in humans in Florida are higher, on the average, than in residents in the rest of the conterminous United States.
2. Evidence indicates that the levels of ^{137}Cs in humans in Florida are attributable to elevated levels of intake, which are primarily due to locally produced foods.
3. Levels of ^{137}Cs in food products vary widely within any general locality but show a consistent geographical pattern of variation within the State.
4. Elevated levels of ^{137}Cs in animal products appear to be due to elevated levels of intake by the animals in the form of locally grown forages. As a corollary, plants appear to play a key role in the appearance of ^{137}Cs in the Florida biosphere.
5. The ^{137}Cs currently in the Florida biosphere is of atmospheric origin and is delivered to plants either directly by foliar and floral deposition or through delivery to and subsequent uptake from the soil and surface matter.
6. Evidence suggests that there is an environmental mechanism concentrating ^{137}Cs to an unusual degree in Florida, and
7. It appears quite likely that uptake from the soil plays a significant role in the levels of ^{137}Cs in Florida plants and thus in the entire Florida biosphere.

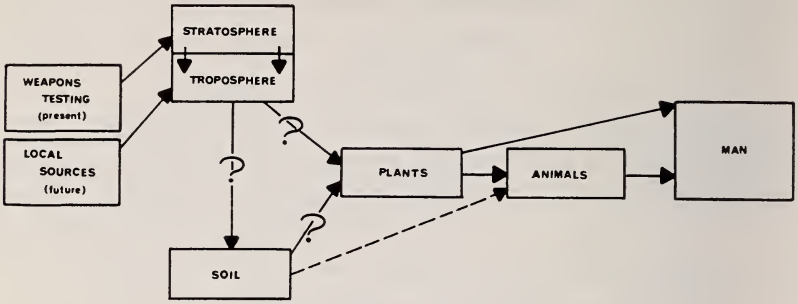

Fig. 1. Significant pathways to man for cesium-137 in Florida. Question mark indicates pathway of uncertain role, i.e. needing further investigation. Broken line indicates unusual pathway, significant in special cases. Other pathways: 1) inhalation by man or animals, not significant in this situation; 2) water to man or to animal to man, little evidence on the basis of radionuclide analysis of water; 3) water to plant and hence to man, possible influence in affecting availability and uptake of deposited material from the soil or the surface.

Fig. 1 shows significant pathways by which ^{137}Cs reaches man.

Experimental Findings

Research activities in the State, concentrated most recently at the University of Florida, support the seven-point summarization of unusual behavior of cesium in Florida.

1. Cesium-137 body burdens of 251 Florida residents measured with the University of Florida whole-body counter from 1965 through early 1968 (G. S. Roessler et al., 1969) were two to three times the levels observed in 20 non-residents and several times those recently reported by Gustafson and Miller (1969) for the conterminous United States during the same period (Fig. 2). Analysis of this data by year shows that the levels did not drop with time as rapidly as levels reported in other areas of the United States. These levels also appear to have a characteristic geographic distribution within the State with highest average body burdens in residents of the central part of Florida and lowest average burdens in residents of northwestern Florida.

In a 1966 study of children at the Tampa, Florida station of the United States Public Health Service (USPHS) Institutional Total Diet Sampling Network, ^{137}Cs body burdens were estimated by urine measurements and also measured by whole-body counting. These body burdens were found to be two to three times those

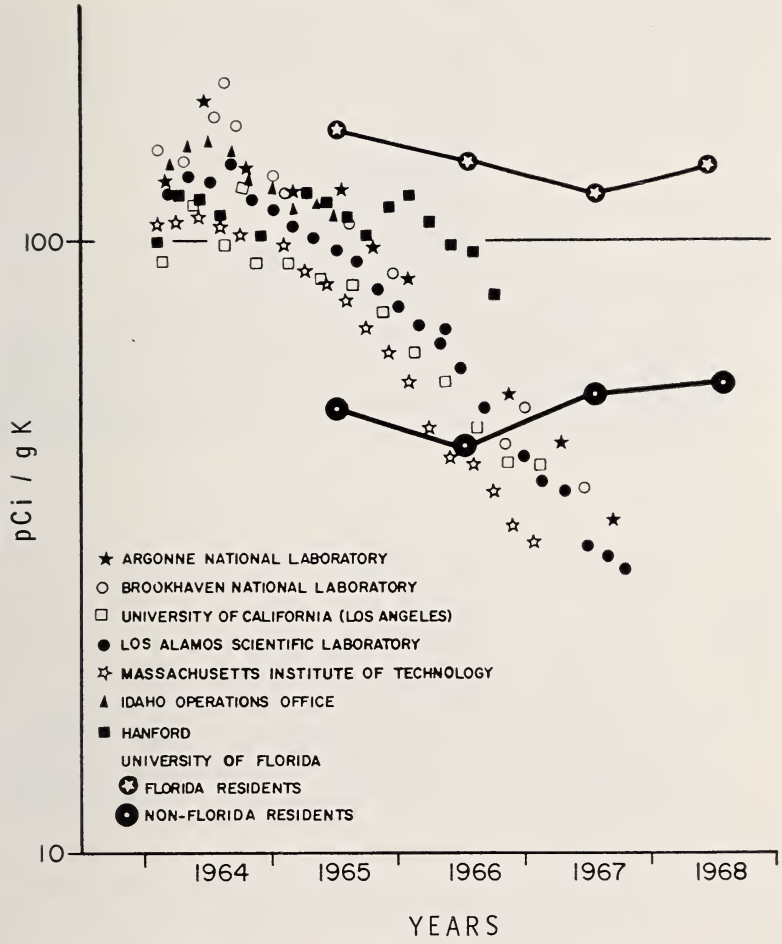

Fig. 2. Comparison of Florida cesium-137 body burdens to body burdens in seven United States locations.

found in children from five other locations in the United States (Cahill et al., 1968).

2. Likewise, ^{137}Cs intake levels at this station were consistently higher from 1962 to 1968 than the network average (U. S. Public Health Service, 1962-68). Furthermore, elevated levels of ^{137}Cs have been consistently observed in Florida milk (Fig. 3; U. S. Publice Health Service, 1959-68; Florida State Board of Health, 1964-

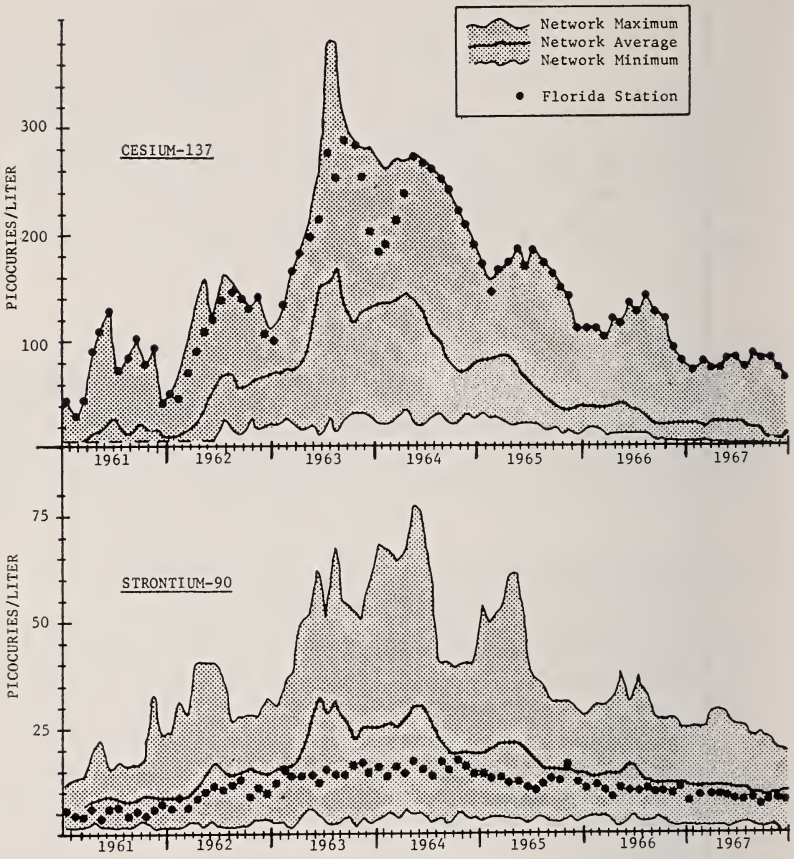

Fig. 3. Cesium-137 and strontium-90 in the Pasteurized Milk Network. Comparison of the Florida station to national average and ranges.

68; C. E. Roessler et al., 1969a) and in studies at University of Florida laboratories, elevated levels of ^{137}Cs were found in 1966 and 1967 in Florida-produced beef and vegetables (C. E. Roessler et al., 1967, 1968, 1969b).

The assumption that human ^{137}Cs body burdens are influenced significantly by the elevated levels in selected Florida foods is supported by several observations of body-burden modification associated with change of residence. The ^{137}Cs body burdens of three subjects measured in 1966-1968 showed a several-fold increase during the months immediately following their arrival in the State (G.

S. Roessler et al., 1969). On the other hand, J. Golden, in an unpublished communication, reported that an individual who changed his residence from Florida to New Mexico in 1966 was found upon arrival to have an unusually high body burden, five times that of the average New Mexico resident. After two years his body burden had decreased to near the average New Mexico level.

3. In addition to being higher than the national average, ^{137}Cs levels in milk, feed-lot beef, and vegetables show a consistent geographical pattern of variation within the State (Florida State Board of Health, 1964-68; C. E. Roessler et al., 1969a, 1969b, 1968, 1967). The lowest levels were observed in northwestern Florida and higher levels were found in the rest of the State (Fig. 4). There is some evidence to indicate that within Peninsular Florida the highest levels occur in the central part of the State.

4. The geographic distribution of ^{137}Cs in milk and beef (C. E. Roessler et al., 1969a, 1969b, 1967) is similar to that found in 1965-1967 in dairy feeds, especially grasses, according to unpublished studies at this laboratory made in collaboration with Williams and Nettles of the Florida State Board of Health. The levels in grass-fed beef were observed to be considerably higher than in feed-lot beef (C. E. Roessler et al., 1968). Furthermore, studies of individual feed components at several farms identified locally grown forage as the principal source of ^{137}Cs intake in these instances (Porter et al., 1966).

5. Since there is no evidence of a local (Florida or southeastern U. S.) source of ^{137}Cs, the presence of this nuclide is attributed to world-wide fallout from nuclear weapons testing. The widespread distribution of ^{137}Cs in the State also suggests that the ^{137}Cs is of atmospheric origin. If this is the source, the elevated levels of this nuclide in the State must be due to either (a) an unusually high delivery of this nuclide to the Florida environment or (b) an unusually high concentration of the delivered material.

6. According to the reported generalized latitudinal distribution of fallout, deposition levels in Florida should have been considerably less than at the latitude peak fallout (about 50° N) and should have decreased appreciably from north to south (List et al., 1965). Furthermore, Federal Radiation Council Report No. 6 (1964) places Peninsular Florida in "an expected lesser fallout area compared to

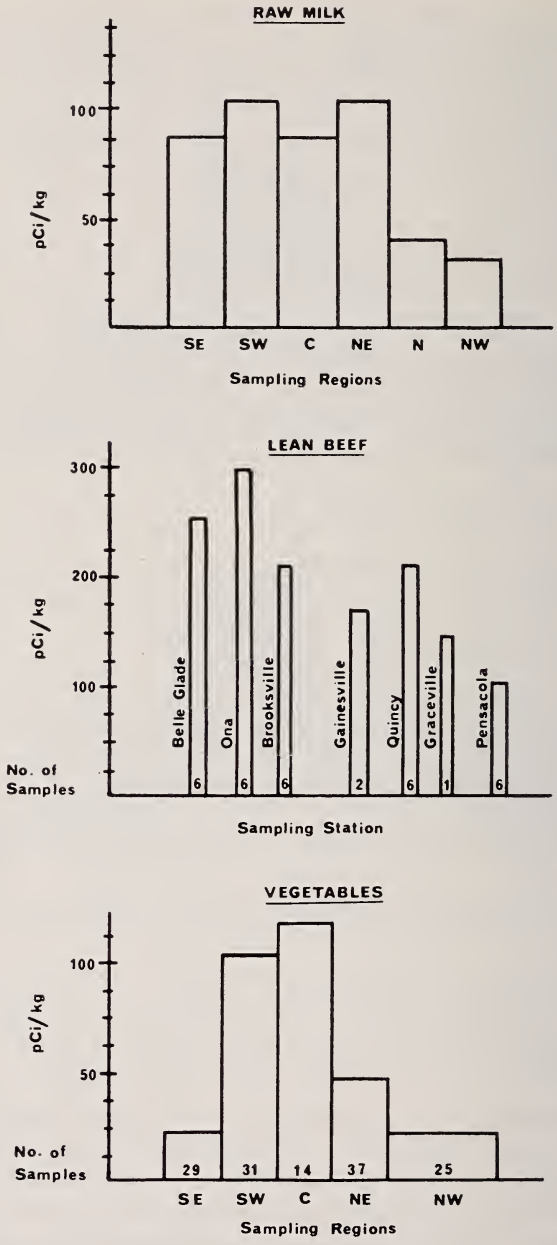

Fig. 4. Geographic variation of cesium-137 in Florida milk, beef, and vegetables in 1967.

'wet' eastern United States because of its subtropical location", and leaves only northwestern Florida in the "wet" (high deposition) category.

These generalizations about fallout distribution are supported by the observed levels of ^{90}Sr, another biologically significant fission product with an abundance in fallout comparable to ^{137}Cs. The ^{90}Sr concentration in soil was less at Miami in southern Florida than at Jacksonville in northern Florida (List et al., 1965); the levels in those biological media examined (milk and total diets) were not particularly high (Fig. 3); and the levels in milk (the only reported media examined on a statewide basis) generally decreased from north to south in the State (Florida State Board of Health, 1964-68; C. E. Roessler et al., 1969a). Similarly, in the unpublished study already mentioned, the ^{90}Sr levels in Florida dairy feeds were not particularly high and also generally decreased from north to south.

Although there is a contrast between the distribution of ^{90}Sr and ^{137}Cs in the State, there is no basis to suggest an unusual fractionation of fission products in the atmosphere resulting in a particularly ^{137}Cs-rich fallout being delivered to sections of Florida (Hardy and Chu, 1967). Rather, it is more reasonable to assume that some mechanism exists which results in an unusual concentration of ^{137}Cs (and possibly other nuclides) in the Florida biosphere.

7. Possible critical factors in this mechanism include soil characteristics, climate, cultivation practices, unique vegetation types, and unique rates of vegetation growth. In one investigation, pangolagrass (*Digitaria decumbens*) was suggested as the primary source of elevated intake by dairy cattle in the Tampa, Florida, milkshed (Porter et al., 1966). In another study this grass was shown to accumulate ^{137}Cs to higher levels than several other common Florida pasture grasses (Cromroy et al., 1967). However, it appears that a species effect alone does not account for the elevated levels of ^{137}Cs in milk from parts of the State where pangolagrass is not grown nor for the elevated levels observed in other vegetation.

Langham (1965) and Fredricksson et al. (1966) report that the primary source of ^{137}Cs currently in the biosphere is from the atmosphere by direct foliar deposition on plants and that uptake from the soil is very limited because of fixing of cesium in an unavailable form on clay minerals in the soil, particularly in mineral soils of the temperate zone. However, the persistence of ^{137}Cs levels in Florida

media during the present period of decreasing deposition, particularly the persistence in milk from parts of the State having the highest levels of this nuclide (C. E. Roessler et al., 1969a), suggests a significant local reservoir of available cesium, the soil.

Limited investigations of the availability to plants of the ^{137}Cs in Florida soils support the importance of soil cesium. In a pilot study, there was significant uptake from Florida soils by several grasses (Cromroy et al., 1967).

In a study of 12 Florida, Alabama, and Ohio soils, Cummings et al. (1969) demonstrated a negative power function relationship between ^{137}Cs uptake by oats grown two weeks in containers in an environmental chamber and the experimentally determined ^{137}Cs fixing capacity of these soils. The ^{137}Cs fixing capacity of the five Florida soils was found to be considerably less than that of the other soils and the uptake by oats was indeed greater from the Florida soils than from the others.

Work in progress by W. E. Bolch, another University of Florida investigator, indicates relatively high penetration of the ^{137}Cs into Florida soils; for example, uncultivated pasture lands in central Florida contain measureable amounts of this nuclide below a depth of 6 inches. The findings are consistent with the fact that in the parts of Florida showing the highest ^{137}Cs concentrations in biological media, soils generally have clay fractions of only one per cent or less. It has also been suggested that significant amounts of cesium will be available during recycling in the more tropical parts of the State because of the rapid turnover of organic matter.

Significance of Experimental Findings

Although current levels of ^{137}Cs in Florida are not considered as an immediate health hazard, an unusual concentrating mechanism could result in higher than expected radiation exposures as a result of intentional or inadvertent releases to the environment of this, and possibly other, radionuclides. This condition has potential significance to the siting and operation of nuclear facilities in the State and to the disposal of radioactive waste.

By identifying the critical factors in biospheric concentration of ^{137}Cs, describing relationships between environmental compartments in quantitative terms, and relating present human exposure to levels of ^{137}Cs in the various components, a model can be developed for

predicting the consequences of future releases of this nuclide to the environment. It is possible that the mechanism affecting ^{137}Cs accumulation also affects other nuclides, and an extension of these studies to other nuclides potentially has the same significance as for ^{137}Cs.

Because of the subtropical location, studies in Florida also contribute to the understanding of the behavior of radionuclides in tropical environments, an area in which only a limited amount of work has been done.

Further Research

Because of the apparent unusual ^{137}Cs-concentrating mechanism in Florida, additional research is needed to describe the radiation source-environment-man relationship. In addition to the continuation of measurements of ^{137}Cs body burdens in humans and measurements of the concentrations of this nuclide in various food commodities, other related studies have been initiated at the University of Florida. The roles of deposition and soil characteristics are being examined in an attempt to establish the factors responsible for the unusual ^{137}Cs levels. Other work currently in progress involves determination of the per cent of organic matter in the soils examined for ^{137}Cs content. The roles of climate and cultivation practices represent additional areas for investigation. There is also a need for the development of predictive models to estimate future exposure to ^{137}Cs in the Florida environment. Since it is possible that the factors resulting in unusual ^{137}Cs concentrations and human exposure also influence the behavior of other radionuclides, tracer studies should be performed with other important nuclides.

Acknowledgments

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